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THE RELATION OF THE BODY TEMPERATURE OF CERTAIN COLD-BLOODED ANIMALS TO THAT OF THEIR ENVIRONMENT.

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In a former paper[2] the present writers cited statements from the literature showing that it is rather generally assumed by biologists that the temperatures of the so-called cold-blooded animals approximate very closely the temperatures of their surrounding media, so closely, in fact, that the temperature of the medium may be assumed to be the temperature of the animal in question. It was also shown from citations to the original experiments that such evidence as we have in regard to the relation of the temperature of these cold-blooded animals to that of their surroundings is to the effect that the temperature of the animal is usually somewhat above that of the water in which it is living. At that time we described experiments upon the earthworm, *Lumbricus agricola*, which indicated that for temperatures from 10° to 20° C. the temperature of the earthworm very closely approximated that of the water in which it was immersed, often being the same.

The brief review of the literature made at that time indicated a lack of uniformity in results hardly believable. A more careful survey of the available papers upon the subject of temperature determinations in living animals convinced us of the advisability of undertaking an experimental study of temperature relations in a series of forms, making use of a uniform method which should be accurate to a degree not attained in any of the previous studies. The present report embodies results obtained in an effort to carry

[1] From the Department of Zoölogy, Oberlin College.

[2] Rogers, Charles G., and Lewis, Elsie M., "The Relation of the Body Temperatures of the Earthworm to that of its Environment," BIOLOGICAL BULLETIN, Vol. XXVII., No. 5, 1914.

forward this work, and while it does not cover as wide a range of forms as we would wish, it does, we believe, give an indication of what we may expect to find in a more comprehensive survey. In this study forms were selected from as widely separated animal groups as possible, fairly wide ranges of temperature were covered, and the changes of temperatures were made both slowly and suddenly.

LITERATURE.

A table was compiled from the data obtained from various reports, which though brief indicates that in most cases the investigators made use of mercurial thermometers. Many make no statements of the means employed or of the ranges of temperature to which the animals were subjected. Dutrochet[1] introduced thermoelectric methods in the determination of the temperature of single bees and colonies, though the more recent work of Phillips and Demuth[2] is more comprehensive. The latter authors used a method sensitive to a difference of temperature of 0.09° F., and found that the bees in a temperature below 57° F. tend to form clusters and to raise their temperature decidedly above that of the air, but between 57° and 69° the temperature of the hive follows that of the air. Work very similar to this has been done upon plants. John H. Ehlers[3] quotes various reports which gave the temperatures of leaves as high as 16° above the shade temperature of the air. In his own work Ehlers used a potentiometer method which enabled him to neglect a number of outside factors in his thermo-couple determinations, and obtained in the pine leaf temperatures 2° to 10° above the shade temperature of the air.

Table I., compiled from various sources, gives an idea of the diversity of results obtained by different observers, and the incompleteness of the data available. For example we find in regard to carp alone the following reports:

Hunter[4]	carp	1.9° to 3.5°	above	surrounding	water
Buniva	"	3.0°	"	"	"
Desprets	"	0.86°	"	"	"

[1] Dutrochet, *Ann. d'Hist. Nat.*, 2, Zoöl. 13, p. 5.

[2] Phillips and Demuth, *Bull. U. S. Dept. Agriculture*, No. 93,

[3] Ehlers, John H., *American Journal of Botany*, 2, 1915, pp. 32–70.

[4] Reported by Davy, *Ann. de Phys. et de Chem.*, XXXIII., 1826, p. 180.

TABLE I.

Form.	Range.	Conditions and Method.	Temperature of Animal Above that of Environment.	Observer.
Medusa.....	......	....	0.27°	Valentin
Earthworm..	56° F.	Several in glass by thermometer	2.0°–2.5° F.	Hunter
Leeches.....	56–54°	Several in glass by thermometer	1.0°–1.5°	Hunter
Worms......	......	....	4.4–5.8° F.	Davy
Ceylon jungle leech......	......	....	Same as water or air	Davy
Echinoderms	......	....	0.40°	Valentin
Snails.......	54° F.	Several in glass by thermometer	1.25° F.	Hunter
Snail........	76.25° F.	....	0.25° F.	Davy
Oyster......	82°	....	Same as water	Davy
Crustacea...	72–80° F.	....	1° below to same as water	Davy
Insects......	62–83° F.	....	8° below to 10.5° above	Davy
Bees........	19.2° C.	Individuals—thermoelectric	0.18° C.	Dutrochet
"	......	Hive	0.25° C.	Dutrochet
"	......	....	0.55–10.5° C.	
"	57–69° F.	Thermoelectric	Same as air	Phillips and Demuth
"	Below 57°	"	Form clusters and raise temperature	"
Fishes:				
Bonita....	80.5–78° F.	Heart muscle	1.5–5°	Davy
Trout.....	86–40° F.	....	28° below to 2° above	Davy
Eel.......	51° F.	....	same as air	Davy
Fishes(?)..	......	....	0.55° F.	Martin
"	......	....	1.38° F.	Kraft
"	......	....	6.2–9.3° F.	Broussouet
"	......	....	1.2–6.2° F.	"
Carp......	......	....	3° F.	Boniva
"	......	....	0.86°	Depretz
"	66.5° F.	Stomach	1.9–3.5° F.	Hunter
Mackerel....	80.5° F.	"	8.5° F.	Davy
Herring.....	4.6–6.4	....	0.0–1.2° C.	Simpson
Amphibia....	58–86° F.	Rectal temperature	3.0° below to 8.5° above	Davy
Frog........	......	in air	Temp. less than air	Berthold
"	......	in water	same as water	"

Hunter alone stated the temperature of the water in the experiment, 66.5°–65.5° F. Such information is of value as Phillips and Demuth have shown in their report upon the temperature of bees, already referred to.

METHODS.

In the present work the method outlined in the previous paper[1] was followed with the added precautions made necessary by the

[1] Rogers, Charles G., and Lewis, Elsie M., BIOL. BULL., XXVII., 1914, No. 5.

use of a highly sensitive galvanometer made by Leeds and Northrup. This instrument is of the D'Arsonval type and constructed especially for thermo-couple work. The apparatus included thermostat, thermo-couples, switch, galvanometer and scale. The thermostat used in all the work was provided with fans and motor for keeping the water constantly stirred. The thermo-couples were made of No. 32 double cotton covered Advance wire made by the Driver-Harris company, and No. 36 double cotton covered copper wire. Both wires were carefully shellacked before using. In making the couples we followed the method of White.[1] The wires were uncovered for a short distance at the ends, twisted together, dipped into melted resin and then into melted solder. The ends of the wires were handled entirely with grease-free forceps and the wires were protected from physical strain throughout the course of the work. The couples so made were inserted in small glass tubes sealed at one end. The wires were twisted together through the whole length of the tube and the open end of the tube was closed with wax. This protected both wires from moisture. The advance wire between the junctions was enclosed in a small rubber tube extending between the two glass tubes, and around the rubber tube was placed a heavy wall of wool wadding to prevent changes of temperature in this wire. The copper wires of the couples were connected to heavier, well-insulated droplight cord used as leads to the switch and to the galvanometer. Between the lead wire and one of the copper wires of the couple there was inserted about one and a half meters of No. 36 manganin wire to act as a resistance and thus reduce the strength of current from the couple passing into the galvanometer. All junctions were carefully soldered and the manganin wire as well as the junctions were heavily wrapped in wool and placed in a wooden box to provide against changes of temperature. The switch was also protected in a similar way. These precautions were found to be essential as the temperature changes at these points when they were not so protected resulted in wide variations in the readings of the galvanometer. The junctions were kept, so far as possible, at a constant distance of about one half inch from each other. This gave very constant readings.

[1] White, Walter P., *Jour. Am. Chem. Soc.*, XXXVI., 1914, Nov., p. 2300.

During a part of the work a parasitic current such as mentioned by White[1] was present. This parasite was at times entirely absent, or was constant during the period of experimentation, but at other times varied considerably. In order to check perfectly our results we finally made it a practice to determine the value of the parasite, if any, both before and after each reading for the determination of the temperature of a specimen. The value of the parasite was determined by placing the junctions close together in the thermostat and determining the deflection from the zero point on the scale when the couple was thrown into the galvanometer circuit, the galvanometer being set to register (usually) at zero when at rest. A specimen could then be quickly placed upon the proper junction and the deflection due to the difference of temperature between the free junction and the one within the body of the animal determined. It was found to be advantageous for one person to make the galvanometer readings while another read the thermometer in the thermostat and placed the specimens upon, or removed them from the couple. This helped to ensure constant conditions at the couples and made it possible to take galvanometer readings at the instant specimens were removed.

Precision of the Method.

Through a series of preliminary tests it was found that with 1.33 m. of manganin resistance wire introduced into the thermocouple circuit there was an average deflection of 238 mm. on the scale for one degree Centigrade difference in the temperature of the two junctions of the couple. These tests were made at known temperatures which were read with a certified thermometer graduated to hundredths of a degree Celsius and a Beckman thermometer set for the particular temperatures under consideration. The junctions were in each case attached to the thermometer bulbs and the temperatures of the baths were held as constant as practicable to ensure accurate determinations of the electromotive force of the couple. With the value 238 mm. per degree difference in the temperature of the two junctions of a couple temperature determinations accurate to 0.0042° were

[1] White, Walter P., *Jour. Am. Chem. Soc.*, XXXVI., No. 9–10, 1914.

practicable, or by reading to fractions of a millimeter upon the galvanometer scale even smaller fractions could have been estimated though such an estimate was made in only a few cases. The scale used in these readings was placed at a meter distance from the galvanometer and was mounted upon an arc of a circle having a meter radius. This made it unnecessary to make corrections in the readings as would have been necessary if a straight scale had been used. It was possible to determine directly the temperature difference between the two junctions from the deflection, having determined the value of the parasitic current at experiment. Our temperature differences were so small that we did not find it at all necessary to make use of a potentiometer in connection with the galvanometer for this work.

Elimination of Errors.

The elimination of possible sources of error has been touched upon in the description of the methods, but the precautions employed may be summed up briefly. Variations due to differences of temperature in the varying currents of the water bath were checked by keeping the two junctions of a couple very close together and at a constant distance from each other during the course of an experiment. It was found that when this precaution was taken that there was scarcely ever a noticeable difference in the temperature of the water at the two points.

Leakage to the system from stray electric currents was not observed. Tests with the motor employed for stirring the water in the thermostat, the greatest possible source of outside influence, showed no effect whatever upon the system. Variations due to lack of uniformity in the wires used were practically nil. One set of couples was used throughout the whole series of experiments and the wires were carefully protected from strains. Secondary couples were prevented through the careful insulation from temperature changes of all wires and switch connections in the system. Change of resistance due to alterations of temperature of the lead wires would be practically negligible as the wires were heavily insulated and the temperature of the room showed no wide variations during the course of the work. Heat production upon the part of the animals on account of injury or

irritation furnishes a possible source of error, especially in the work upon the clam, but as no sign of increased heat production was observed it may be safely inferred that this could not be of any such amount as seriously to affect the results obtained. In the case of the earthworm and the salamanders there was so little disturbance or irritation that it seems hardly necessary even to suggest the possibility of error.

Discussion of Experiments.

In this discussion of the results of the experiments upon the different forms certain details of procedure are included so as to make clear just what was done in each series of operations. While the general method is the same throughout there were certain minor differences in the manner of handling made necessary by the differences in structure of the animals used.

The results of the investigation have been summarized in the form of a series of tables showing the range of temperatures employed and the temperature relations found to exist between the animal and its environment. In these tables it has been thought wise to omit all except the last two or three observations made at any given temperature. It will be noted that we have not indicated the time elapsed between placing the animal under a given set of temperature conditions and the recording of the final result. This information, while perhaps interesting, does not appeal to us as being of fundamental value in the present study. In general it may be stated that in the case of the worms from one to three minutes was allowed for adjustment to the temperature of the surrounding water; in the case of the larger forms a longer period was required. From one half to three quarters of an hour was required for the adjustment to take place, and frequently a still longer time was allowed.

Experiments upon the Earthworm.—Following the methods employed in the previous work the worms were kept in the cellar or brought into the laboratory as needed. The junction of the thermo-couple, encased in a glass tube of small diameter was inserted in the mouth of the worm and gently passed down into the stomach intestine. The worm was then placed in the water of the thermostat and brought to within about an inch of the

other junction of the thermo-couple. The water in the bath was kept in constant and rather rapid motion. The temperatures reported range from 16.00° to 22.15° C. Work was carried on also at higher and lower temperatures, but proved to be less satisfactory on account of the difficulty experienced in maintaining a constant temperature for the time required for a complete series of observations. So far as carried, however, the results corroborate the data here offered and also the results previously reported. This statement holds for both sudden and for gradual changes of temperature over short ranges.

As will be seen from an examination of the data offered in Table II. the temperature difference between the animals and the water in which they were placed was remarkably low. In six out of the eleven cases reported there was no difference determinable. Two worms showed a temperature of 0.0084° below that of their surroundings, and one a temperature of 0.0084° above that of the water, maintaining this difference for a long time. One worm showed a temperature of 0.042° below that of the water, and one a temperature of 0.084° above. The specimen last mentioned is the only one in the whole series examined which showed so considerable a temperature difference, and seems to us in the light of the results obtained upon the other forms to be an unusual case.

Experiments upon the Clam Anodonta.

The number of animals used in this series of experiments was small, and the work would perhaps have been more satisfactory if a larger number of animals had been employed. In general the results are similar to those obtained in the case of the earthworm. In every case the adjustment of the animal to the temperature of the water in which it was immersed was much slower. This can be accounted for upon the fact that the mass of material was so much greater. Each clam weighed somewhere in the neighborhood of 200–250 grams. The great mass of the shell in addition to the bulk of the fleshy parts of the animal rendered the temperature adjustment slow. The glass-covered junction was inserted into the mouth or pushed in between the visceral mass and the foot. We were not able to determine that one place was

Table II.

In the Tables only the Last Two or Three Readings at any Given Temperature are Included. Fractions of a Millimeter Deflection were not Considered.

Earthworm Series.

No.	Temperature of Bath in Degrees C.	Deflection Due to Difference of T. in Mm. of Scale.	Temperature of Animal Above or Below that of Water.	Actual Temperature of Animal in Degrees C.	Remarks.
1	21.90	10	+0.042	21.942	
		11	+0.046	21.946	
		1	+0.0042	21.9042	
	22.00	5	−0.021	21.979	
		5	−0.021	21.979	
		0	−0.00	22.00	
2	22.15	10	+0.042	22.192	
		3	+0.0126	22.1626	
		2	+0.0084	22.1584	
3	18.00	10	−0.042	17.958	
4	16.00	2	−0.0084	15.9916	
5	16.40	4	−0.0168	16.3832	
		0	0.00	16.40	
6	16.40	0	0.00	16.40	
7	Rapidly changing parasitic current in system—no records made				
8	16.60	4	−0.0168	16.5832	
		7	−0.0294	16.5706	
		2	−0.0084	16.5916	
		0	0.00	16.60	
9	17.40	11	−0.0462	17.3538	
		12	−0.0504	17.3496	
		0	0.00	17.40	
10	16.70	6	−0.0252	16.6748	
		4	−0.0268	17.6832	
		2	−0.0084	16.6916	
	16.40	0	0.00	16.40	
11	16.10	20	+0.084	16.184	
12	Rapidly changing parasitic current—no records made				
13	16.40	2	−0.0084	16.3916	

better than another for the insertion of the junction, though there is of course the possibility that such injury as is inevitable when the glass was crowded through the tissues may lead to some increased heat production. This point should receive

some further study. A glance at the table (Table III.) will indicate the very close approximation of the temperature of the clam to that of the water. In each case an hour or longer was allowed for the animal to remain at a given temperature before making the final reading. In the case of clam 3 it will be noted that the temperature of the clam lagged somewhat behind that of the water both while it was being warmed and being cooled. But even here the difference of temperature between the animal and the water is a matter of hundredths of a degree only.

Table III.

Clam Series—Anodonta.

No.	Temperature of Bath in Degrees C.	Deflection Due to Difference of T. in Mm. of Scale.	Temperature of Animal Above or Below that of Water.	Actual Temperature of Animal in Degrees C.	Remarks.
1	Died during the course of the experiment				
2	21.30	7	−0.0294	21.2706	
		0	0.00	21.30	
3	20.00	10	−0.042	19.958	A very large clam
		9	−0.0378	19.9622	
	24.40	6	−0.0252	24.3748	
		3	−0.0126	24.3874	
	27.70	no data			
	26.00	7	+0.0294	26.0294	Temperature of water decreasing faster than clam
	24.70	19	+0.0798	24.7798	
	18.80	12	+0.0504	18.8504	
4	15.00 Clam taken from water at 15.00° and placed in bath at				
	17.80	1	−0.0042	17.7958	

Experiments upon Salamanders—Diemyctylus viridescens and Amblystoma punctatum.

Our experiments upon the small spotted salamander, *Diemyctylus viridescens*, gave very striking results. In working with the specimens of this species a small wire collar was placed around the body of the animal just back of the fore legs. The long ends of the wire served as a convenient means of handling the animal and for fastening it in the proper position on the glass-covered junction of the thermo-couple. The animal was made to open its mouth and the junction passed down the gullet till it came to lie in the stomach. It was found that after an animal had been through the operation a very few times it no longer made any serious objection to taking the junction. When the animal had been placed upon the junction the whole was then transferred to

the thermostat and near to the free junction. The wire made it possible to remove the animal from the couple and to replace it with a minimum of effort whenever it was necessary to make a reading for the parasitic current in the system. The repeated insertion of the junction seemed to cause no trouble whatever, for the animals were just as lively after a long series of temperature readings as before. It was easy by this way of handling to keep several specimens in the thermostat at one time and to take readings upon the whole series, in regular order, at the different temperatures used.

The method employed gave us no opportunity to investigate the time required for an animal to adjust himself to the temperature of his surroundings, though such information would be of interest. From the very little information we have upon the subject it seems likely that there is a definite mathematical relation between the mass of the animal and the time required for adjustment. The salamanders used were allowed from five to ten minutes to become adjusted to their new conditions when changed from one bath to another which was a few degrees different in temperature. This time is certainly in excess of the minimum required. The salamanders proved to be the most satisfactory of any of the forms studied on account of the ease of manipulation, endurance, etc.

Inspection of Table IV. will reveal the close approximation of the temperature of these animals to that of their environment. In most cases a difference of only a few thousandths or at most of a few hundredths of a degree could be determined. Of the 28 specimens reported 12 showed the same temperature as that of the water in which they were immersed, 10 showed an average temperature 0.01293° below that of the water, and 6 an average temperature 0.01225° above that of the water. From the fact that so many individuals show no variation of temperature at all from that of the water in which they were immersed, and that the deviations above and below the temperature of the water practically balance we believe it safe to say that these animals tend to assume the temperature of the water in which they are living to within a very few thousandths of a degree. It is entirely possible that a longer watching of the temperatures of these

Table IV.

Fractions of a Millimeter Deflection Were Considered in Only a Few Cases.

Salamander Series

No.	Temperature of Bath in Degrees C.	Deflection Due to Difference of T. in Mm. of Scale.	Temperature of Animal Above or Below that of Water.	Actual Temperature of Animal in Degrees C.	Remarks.
1	16.10	0	0.00	16.10	
	19.00	4	+0.0168	19.0168	
2	16.10	2	+0.0084	16.1084	
		0	0.00	16.10	
	19.00	0	0.00	19.00	
3	16.10	0	0.00	16.10	
4	16.10	0	0.00	16.10	
	19.00	1	−0.0042	18.9958	
		0	0.00	19.00	
	15.00	No data			
	18.50	0	0.00	18.50	
		3	+0.0126	18.5126	Above T. of bath
		5	+0.0210	18.521	
5	18.50	1	−0.0042	18.4958	The animals used in experiments 5–11 were in each case taken from water at 15° in which they had been for a long time.
6	18.50	2	−0.0084	18.4916	
		0	0.00	18.50	
7	16.30	3.5	+0.0147	16.3147	
8	16.30	5	−0.0210	16.279	
		2	−0.0084	16.2916	
9	16.30	.5	+0.0021	16.3021	
10	16.40	1	−0.0042	16.3958	
11	16.40	1	−0.0042	16.3958	
	25.70	61.5	−0.2583	25.4417	
	18.50	4.5	−0.0189	18.4811	
	16.70	1.5	+0.0063	16.7063	
12	16.30	0	0.00	16.30	
13	16.30	0	0.00	16.30	
15	1.470	No data			
	15.30	2.5	−0.0109	15.2891	
	18.40	36	−0.1512	18.2488	
	19.30	5	−0.0210	19.2790	
		2	−0.0084	19.2916	
	19.50	2	−0.0084	19.4916	
	22.30	0	0.00	22.30	
16	14.70	0	0.00	14.70	
	15.50	2	−0.0084	15.4916	
	19.70	1	−0.0042	19.6958	
	14.70	0	0.00	14.70	
	15.60	2	−0.0084	15.5916	
	19.90	3	−0.0126	19.8884	
18	15.00	3	+0.0126	15.0126	
	15.00	0	0.00	15.00	
	15.20	2	+0.0084	15.2084	
	15.60	2	+0.0084	15.6084	
	20.40	2	+0.0084	20.4084	
	20.50	0	0.00	20.50	
	15.50	No data			
	20.70	1	−0.0042	20.6958	
	21.60	3.5	−0.0147	21.5853	
20	15.50	No data			
	21.00	4	−0.0168	20.9832	
	21.40	1	−0.0042	20.3958	
	22.00	1	−0.0042	20.9958	

Salamander Series—Continued

No.	Temperature of Bath in Degrees C.	Deflection Due to Difference of T. in Mm. of Scale.	Temperature of Animal Above or Below that of Water.	Actual Temperature of Animal in Degrees C.	Remarks.
21	15.60	1	−0.0042	15.5958	
22	15.60	1	−0.0042	15.596	
23	15.60	No data			
	15.50	1	+0.0042	15.5042	
	16.40	1	+0.0042	16.3958	
	17.80	0	0.00	17.80	
24	17.80	2	−0.0084	17.7916	
25	19.90	5	−0.0210	19.879	
26	19.90	1	−0.0042	19.8958	
27	22.10	0.5	−0.0021	22.0979	
	23.30	0	0.00	23.30	
	22.70	0	0.00	22.70	
28	23.10	1.5	−0.0063	23.0937	
29	18.80	1.5	−0.0063	17.7937	
	20.30	0	0.00	20.30	
	16.50	0	0.00	16.50	
	23.80	0	0.00	23.80	
	25.00	No data			
	30.40	0	0.00	30.40	
	29.70	0	0.00	29.70	
	35.50	0	0.00	35.50	
	33.70	0	0.00	33.70	
	32.50	1	+0.0042	32.5042	
30	17.50	No data			
	31.70	1	−0.0042	31.6958	
		0	0.00	31.70	
31	31.70	0	0.00	31.70	

Experiments made upon a single specimen of *Amblystoma punctatum* gave the following

	16.00	10	−0.042	15.958	
		3	−0.0126	15.9874	
		0	0.00	16.00	
	27.00	2	−0.0084	26.0916	

animals would have resulted in eliminating even the small differences recorded.

Only one specimen of *Amblystoma punctatum* was studied. The results obtained from a very few temperature determinations indicate the same general adjustment as occurs in the other forms.

Experiments upon the Goldfish.

Temperature determinations were made upon a few specimens of gold fish, varying in weight from 11 to 26 grams. The junction was inserted into the mouth and pushed down through the gullet into the stomach cavity. The animal had to be bound upon a

frame with cheese cloth in order to keep the junction in place, and this was done in such a way as not to interfere in any way with the passage of water over the gills. The animals were less tractable than the salamanders and it was found difficult to keep them in a single position near to the free junction of the couple for a sufficient length of time to make a thoroughly satisfactory series of readings. Just at this period in our work we were annoyed by the present of a rather large and fluctuating parasitic current in the system, so only one set of readings is here reported. As far as the work upon the fishes was carried a temperature adjustment to within one or two hundredths of a degree was indicated. The figures in Table V. give the determinations as made.

TABLE V.

Goldfish.

No.	Temperature of Bath in Degrees C.	Deflection Due to Difference of T. in Mm. of Scale.	Temperature of Animal Above or Below that of Water.	Actual Temperature of Animal in Degrees C.	Remarks.
1	22.17	0	0.00	22.17	
		0	0.00	22.17	
		1	+0.0042	22.1742	
		0	0.00	22.17	
	25.00	16	−0.0672	24.9328	
		14	−0.0588	24.9412	
		5	−0.0210	24.0790	
		3	−0.0126	24.9874	
	21.60	4	+0.0168	21.6168	

SUMMARY AND CONCLUSIONS.

We find that the earthworm and the small salamander quickly and closely adjust their body temperatures to that of their environment, the adjustment coming in most cases to within a few thousandth of a degree Celsius over the ranges between 16°–25° for the earthworm and 16°–35° for the salamander.

Clams and goldfish make the same adjustments but require a longer time, from one half hour to one hour being required for a shift of 3–6 degrees Celsius. There is evidently in the forms studied no mechanism for the regulation of heat production or for heat loss from the body. Such heat as is produced in the body is at once given off to the surrounding medium.

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